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Preliminary MRI Reference Data for Fetal Thyroid Size and Signal Intensity Ratios in Fetuses Without Known Thyroid Disease

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Abstract

Background

Fetal magnetic resonance imaging (MRI) is increasingly used for prenatal evaluation; however, reference data for fetal thyroid morphology and signal characteristics on MRI in fetuses without known thyroid disease have not been established.

Objective

To characterize fetal thyroid size and T1-weighted signal intensity ratios on MRI and derive preliminary gestational age-specific reference data for fetuses without known thyroid disease.

Methods

We retrospectively reviewed fetal MR examinations performed between January 2020 and December 2025. On T1-weighted images, the thyroid was identified as a hyperintense structure in the neck. Manual regions of interest (ROIs) were used to measure thyroid area, perimeter, transverse and longitudinal diameters, and thyroid-to-muscle signal intensity ratios (SIRs). Two blinded radiologists independently performed all measurements. Associations of thyroid measurements with gestational age and estimated fetal weight, and interreader agreement (Bland–Altman analysis) were assessed.

Results

In total, 338 fetuses (16–40 weeks of gestation) were included, with most examinations performed between 28 and 35 weeks. Thyroid area correlated moderately with gestational age (r = 0.617) and estimated fetal weight (r = 0.566). Thyroid perimeter, as well as transverse and longitudinal diameters, increased with gestational age. Maximum and mean SIRs showed weak positive correlations with gestational age. Bland-Altman analysis showed wide limits of agreement for thyroid area and diameter measurements.

Conclusions

This study provides preliminary MRI reference data for fetal thyroid size and SIRs at 28–35 weeks of gestation. Interreader variability and the lack of diagnostic validation limit their application to individual fetuses.

INTRODUCTION

Fetal magnetic resonance imaging (MRI) has become increasingly important for the evaluation of fetal development and the detection of congenital anomalies. This growing significance is due to recent advances in rapid pulse sequences, coil technology, and image reconstruction software, which have enhanced image quality, reduced motion artifacts, and enabled the acquisition of high-quality qualitative and quantitative data [1, 2]. While ultrasound remains the primary imaging modality for evaluating the fetal thyroid, fetal MRI has emerged as a valuable complementary tool owing to technological advances that have improved image quality and diagnostic capability [2].

The role of fetal MRI in evaluating various fetal organ systems, particularly the central nervous system, is well established. Owing to its excellent soft tissue contrast and multiplanar imaging capabilities, fetal MRI provides valuable complementary information to ultrasonography [1, 3, 4]. However, its application in fetal thyroid assessment remains limited. The fetal thyroid plays a critical role in fetal growth and neurodevelopment, and accurate evaluation is essential for detecting abnormalities that may adversely affect fetal development and postnatal outcomes [5, 6]. Although ultrasonography remains the primary imaging modality for fetal thyroid evaluation, the increasing use of fetal MRI in clinical practice highlights the need for a better understanding of fetal thyroid morphology and signal characteristics on MRI in fetuses without known thyroid disease.

Compared with ultrasonography, relatively few studies have investigated fetal thyroid assessment using MRI [7–10]. Notably, Fujii et al. demonstrated that fetal thyroid signal intensity on T1-weighted MRI correlated with fetal thyroid function, suggesting that MRI may provide functional information in addition to detailed morphological assessment [10]. However, standardized gestational age-specific reference values for fetal thyroid morphology and T1-weighted signal intensity have not yet been established.

Therefore, the purpose of this study was to establish gestational age-specific reference values for fetal thyroid size and thyroid-to-muscle signal intensity ratios on MRI in fetuses without known thyroid disease and to derive preliminary gestational age-specific reference data for weeks 28–35.

METHODS

Patients

We reviewed consecutive fetal MR examinations performed between January 2020 and December 2025. Fetuses were eligible if MRI included the neck region and fetal biometry by ultrasonography was available within 1 week before or after MRI. Maternal medical records were reviewed for thyroid disease, endocrine laboratory findings, and exposure to antithyroid medications during pregnancy. Available prenatal fetal screening results, including fetal thyroid assessment when available, and neonatal newborn screening results were reviewed to identify thyroid abnormalities. Of the 419 initially identified examinations, 81 were excluded because of inadequate thyroid visualization due to limited imaging coverage or fetal motion (n = 48), suspected fetal growth abnormalities (n = 24), maternal or fetal thyroid disorders (n = 5), or the absence of ultrasonographic fetal weight measurements within 1 week of MRI (n

= 4). The final study cohort comprised 338 fetuses. Fetal MRI was performed for various clinical indications, including the evaluation of suspected placental adhesions (n = 136), uterine abnormalities (n = 69), fetal central nervous system abnormalities (n = 30), and other suspected fetal anomalies. Fetuses referred for suspected non-thyroid abnormalities, including suspected central nervous system abnormalities, were not excluded solely on the basis of the referral indication if no maternal or fetal thyroid disease, thyroid-related medication exposure, thyroid abnormality on available prenatal screening or MRI, or abnormal newborn screening result was identified.

Imaging

All MRI studies were performed using a 1.5-T MR system (Magnetom Avanto; Siemens Healthcare, Erlangen, Germany) with a 6-channel body matrix coil. All fetuses underwent three-dimensional (3D)-fat-suppressed T1-weighted gradient-echo imaging using the DIXON technique (repetition time/echo time [TR/TE], 4.5/2.19 ms; flip angle, 15°; field of view, 400 × 300 mm; slice thickness, 3.0 mm; slice gap, 0 mm; number of slices, 30; bandwidth, 500 Hz/pixel; number of excitations [NEX], 1; acquisition time, 24 seconds) in the transverse plane. Half-Fourier acquisition single-shot turbo spin-echo (HASTE) sequences (TR/TE, 937/112 ms; flip angle, 110°; field of view, 400 × 400 mm; slice thickness, 6.0 mm; slice gap, 4.2 mm; number of slices, 30; bandwidth, 504 Hz/pixel; NEX, 1; acquisition time, 28 seconds) were obtained through the maternal body in at least two of the three planes: transverse, sagittal, and coronal planes. T1-weighted images were used for all quantitative measurements, whereas HASTE images were used for anatomical localization of the thyroid. All sequences were acquired during free maternal breathing and without maternal sedation.

Interpretation of MRI findings

One radiologist (M.S., with 11 years of experience in fetal MRI interpretation), who was blinded to all clinical information, retrospectively evaluated all fetal MR images. The fetal thyroid was identified as a hyperintense structure in the neck on T1weighted MR images. A region of interest (ROI) encompassing the largest possible area of thyroid parenchyma was manually placed on the slice demonstrating the largest thyroid cross-sectional area, and the ROI area was automatically calculated. The maximum, mean, and minimum signal intensities (SIs) of the thyroid gland were recorded. In addition, to obtain the SIs of the neck muscles, three circular ROIs were manually placed on the slice showing the greatest thyroid SI. The muscle SI was calculated as the mean SI of the three circular ROIs [10]. The maximum, mean, and minimum thyroid-to-muscle SI ratios (SIRs) were calculated for each case as follows: SIR = thyroid SI/muscle SI. The outline of the thyroid was manually traced on the same image to measure its perimeter. The transverse and longitudinal thyroid gland diameters were measured. To assess interreader reliability, a second radiologist (Y.O., with 13 years of experience in fetal MRI interpretation), who was blinded to all clinical information, independently repeated all measurements.

Statistical analysis

All statistical analyses were performed using SPSS version25 (IBM). Spearman's rank correlation coefficients were calculated to assess the relationships between gestational age or estimated fetal weight and fetal thyroid area, perimeter, diameters, and thyroid-to-muscle signal intensity ratios (SIRs). For construction of the nomograms, measurements obtained by reader 1 were used. For each gestational week, thyroid area, perimeter, transverse diameter, longitudinal diameter, and mean and maximum SIRs were summarized as the mean and standard deviation (SD). Gestational week-specific descriptive reference ranges were calculated as the mean ± 1.96 SD and were presented only for gestational weeks 28–35 because the sample sizes outside this range were limited. Interreader agreement for thyroid morphological parameters and the maximum and mean SIRs was assessed using Bland–Altman plots. A two-sided P value < 0.05 was considered statistically significant.

RESULTS

A total of 338 fetuses, ranging from 16 to 40 weeks of gestation, were analyzed. The most common indication for fetal MRI was the evaluation of suspected placental adhesions (136/338, 40%). Most examinations (276/338, 82%) were performed between 28 and 35 weeks of gestation, whereas only 16 examinations were performed before 24 weeks of gestation.

The thyroid area increased progressively with gestational age and estimated fetal weight (Fig. 1). The correlation with gestational age (r = 0.617) was stronger than that with estimated fetal weight (r = 0.566). The thyroid perimeter, as well as the transverse and longitudinal diameters, also increased with gestational age (Fig. 2). For these parameters, correlations with gestational age were also stronger than those with estimated fetal weight (r = 0.539, 0.453 and 0.538 vs. 0.490, 0.415, and 0.492, respectively). The mean and mean ± 1.96 standard deviation (SD) of the thyroid area and perimeter for gestational weeks 28 to 35, which had sufficient sample sizes (n ≥ 14 per week), at each gestational week are shown in Fig. 3.

Regarding the SIRs, maximum and mean SIRs were weakly positively correlated with gestational age (r = 0.255 and 0.175, respectively), whereas minimum SIR was weakly negatively correlated with gestational age (r = -0.217) (Fig. 4). Similar but weaker associations were observed with estimated fetal weight (r = 0.213, 0.140, and − 0.199, respectively). The maximum and mean SIRs showed a gradual increase with gestational age (Fig. 5).

The mean interreader differences and 95% limits of agreement for thyroid morphological parameters and maximum and mean SIRs are shown in Fig. 6. The limits of agreement were 6.20 ± 89.94, 0.55 ± 31.05, 1.55 ± 3.55, and − 0.06 ± 5.78 for thyroid area, perimeter, transverse diameter, and longitudinal diameter, respectively. For the T1-related parameters, the limits of agreement were − 0.07 ± 0.79 for the maximum SIR and − 0.07 ± 0.47 for the mean SIR.

DISCUSSION

Our study provides valuable insights into the assessment of the fetal thyroid using MRI across gestational ages. We derived preliminary gestational age-specific reference data for fetal thyroid size and SIRs at 28–35 weeks of gestation. These data describe the distributions of thyroid measurements in the study cohort and provide a basis for further validation. The main findings are that MRI can effectively visualize the fetal thyroid as early as 16 weeks of gestation, with thyroid measurements generally increasing with gestational age.

Previous ultrasonographic studies have established nomograms for fetal thyroid size according to gestational age [9]. On ultrasonography, the normal fetal thyroid can be visualized in the anterior neck surrounding the trachea from approximately 12 weeks of gestation [9, 11, 12]. In our study, the thyroid gland was visible on MRI at the earliest gestational age of 13 weeks, but this case was excluded from the analysis due to unavailable estimated fetal weight. Among the included cases, two fetuses were examined at 16 weeks of gestation, and the thyroid was visible in both.

Fetal assessment using MRI is significantly affected by fetal position relative to the mother and by fetal movement [3, 4]. These factors can affect the optimal imaging plane for thyroid visualization. Moreover, in our study, the MRI examinations were not specifically designed for thyroid evaluation but were performed for other clinical indications, such as placental assessment. Therefore, although variability was observed in the measurements, fetal thyroid size, as reflected by thyroid area, perimeter, and diameters, increased with advancing gestational age, showing moderate to strong correlations with gestational age and estimated fetal weight. The slightly stronger association with gestational age suggests that thyroid growth follows a relatively consistent developmental trajectory that is more tightly linked to gestational maturation than to variations in somatic growth. This is consistent with known embryological and endocrine maturation processes, in which thyroid development progresses in parallel with gestational milestones [13].

The maximum and mean SIRs of the fetal thyroid g showed weak but statistically significant positive correlations with gestational age. Thyroid SI on T1-weighted images may reflect the viscosity of the thyroid colloid, which is mainly composed of thyroglobulin [10]. The stability of the SIRs in our study is consistent with previous findings that the concentration of thyroglobulin within the thyroid gland remains relatively constant during fetal life [14, 15]. However, we observed increased variability in SIRs at 35 weeks of gestation. This variability could be attributed to the larger size of the fetus and fetal thyroid in the third trimester, potentially leading to greater measurement variability and reduced image quality. These findings suggest that caution should be exercised when interpreting fetal thyroid measurements on MRI in the third trimester, particularly after 35 weeks of gestation.

Bland–Altman analysis demonstrated interreader variability in thyroid measurements. The limits of agreement for thyroid area and diameters were wide relative to the measured values, indicating that reader-dependent differences should be considered when interpreting individual measurements against the proposed reference ranges. Manual delineation and variability in measurement plane selection may have contributed to these differences. Further standardization of the measurement procedure and

evaluation of reproducibility are needed before these reference ranges can be applied routinely in clinical practice.

This study has several limitations. First, because the cases were retrospectively selected based on clinical indications for fetal MRI, selection bias may have been present. In addition, the imaging protocol was not specifically designed for thyroid evaluation, resulting in variability in thyroid imaging planes among examinations. The wide interreader limits of agreement relative to thyroid size limit the precision with which individual measurements can be interpreted against the proposed reference ranges. In addition, the ability of these ranges to distinguish normal from abnormal fetal thyroid findings was not evaluated. Although our study included fetuses from 16 to 40 weeks of gestation, reference values were established only for weeks 28 to 35 due to limited sample sizes at earlier and later gestational ages. Further research should focus on refining MRI techniques for fetal thyroid evaluation and exploring their clinical applications in the prenatal diagnosis and management of thyroid disorders.

CONCLUSIONS

This study provides preliminary gestational age-specific reference data for fetal thyroid size and thyroid-to-muscle signal intensity ratios on magnetic resonance imaging at 28–35 weeks of gestation. Further validation and improved measurement reproducibility are needed before these data can be used to assess abnormalities in individual fetuses.

Declarations

Author Contribution

M.S. conceived the study, developed the protocol, and drafted the main manuscript text. M.S., Y.O., and K.M. were responsible for data collection and curation. T.I. reviewed and edited the manuscript. H.O. supervised the study design and overall conduct. All authors reviewed and approved the final manuscript.

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Figures

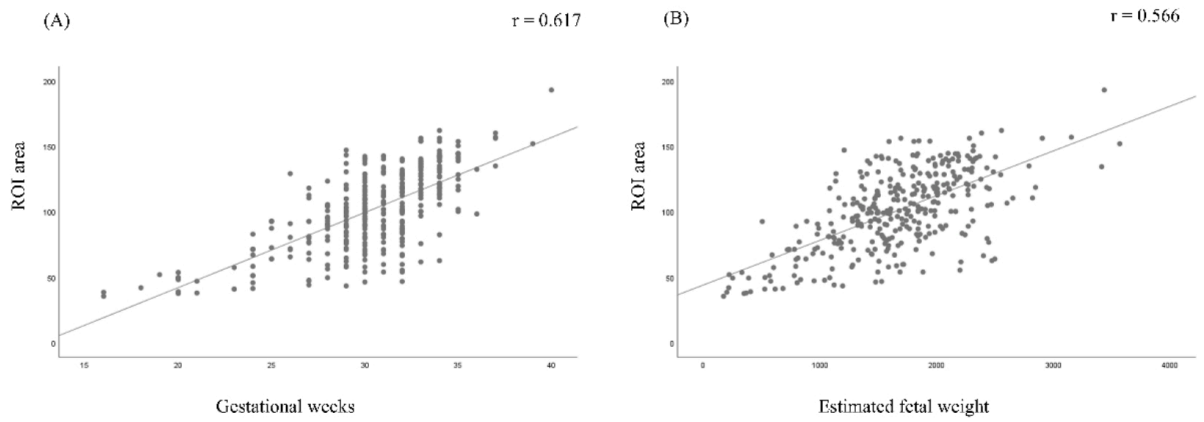


Figure 1

Scatter plots of thyroid area versus gestational age (a) and estimated fetal weight (b)

ROI, region of interest.

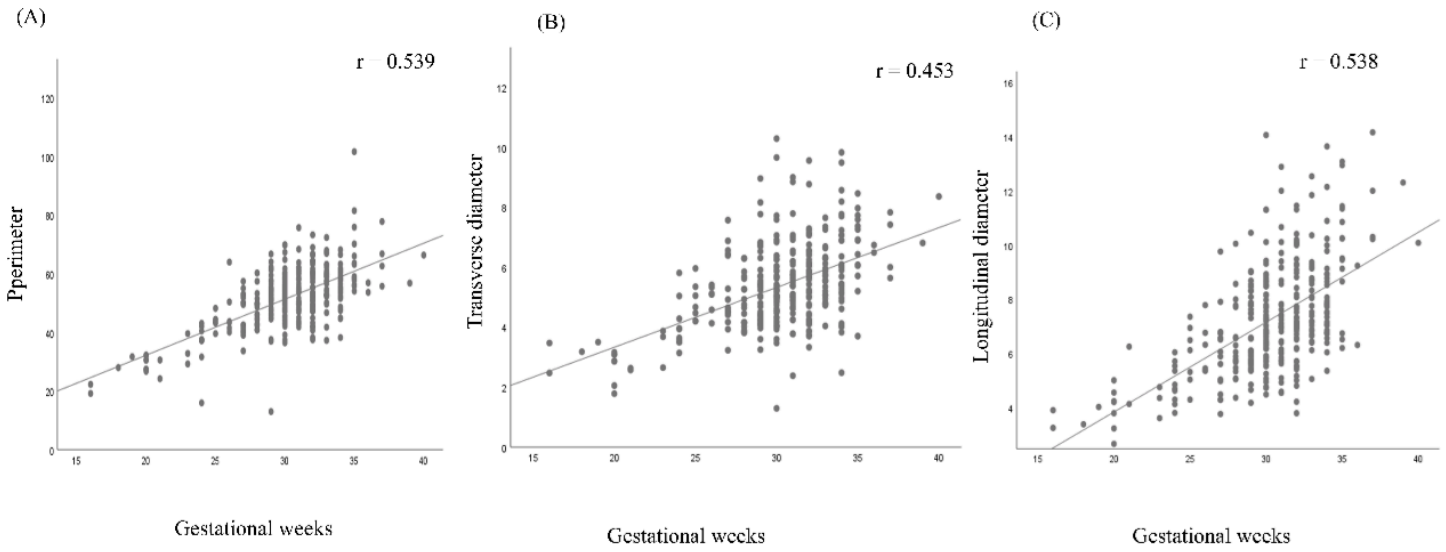


Figure 2

Scatter plots of thyroid perimeter (a), transverse diameter (b), and longitudinal diameter (c) versus gestational age.

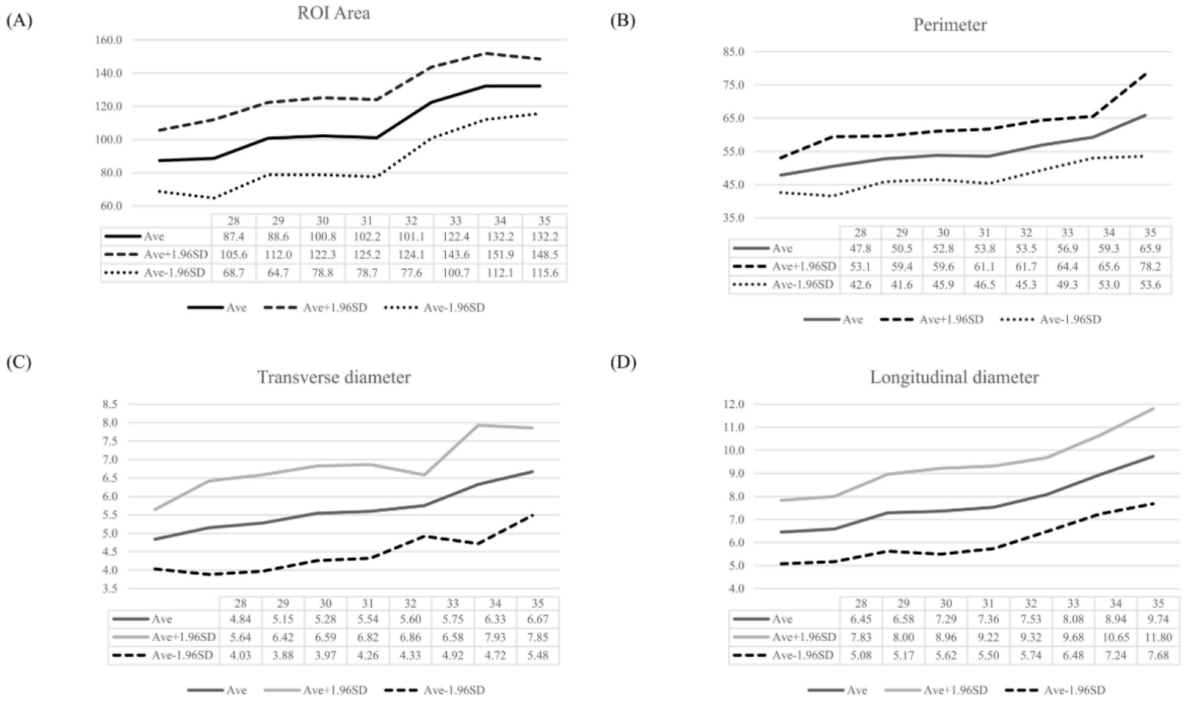


Figure 3

Nomograms of the mean and mean ±2 standard deviations (SDs) of the thyroid area (a), perimeter (b), transverse diameter (c), and longitudinal diameter (d) for gestational weeks 28 to 35.

ROI, region of interest.

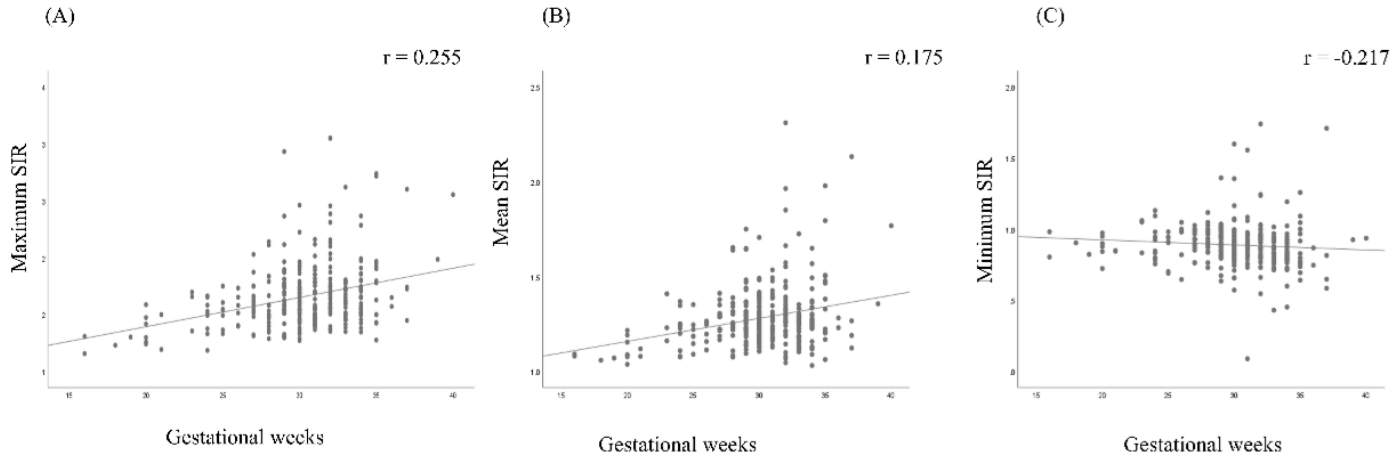


Figure 4

Scatter plots of the maximum (a), mean (b), and minimum (c) T1-weighted thyroid-to-muscle signal intensity ratios (SIRs) versus gestational age.

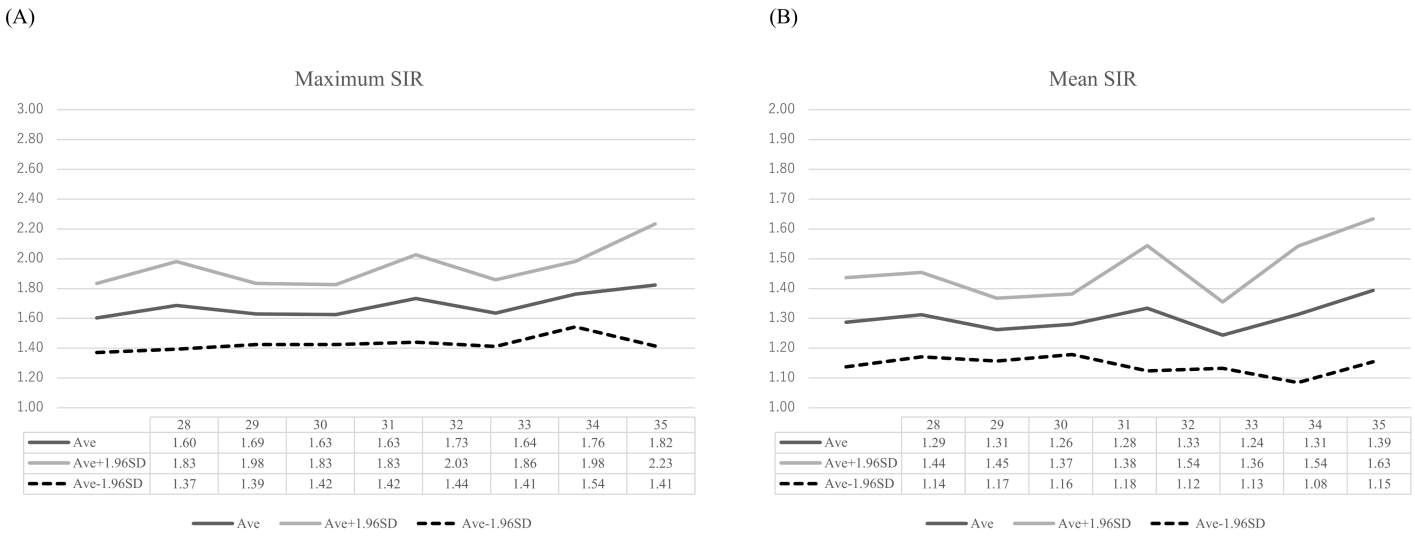


Figure 5

Nomograms showing the mean and mean ± 2 standard deviations (SDs) of the maximum (a) and mean (b) thyroid-to-muscle signal intensity ratios (SIRs) for gestational weeks 28 to 35.

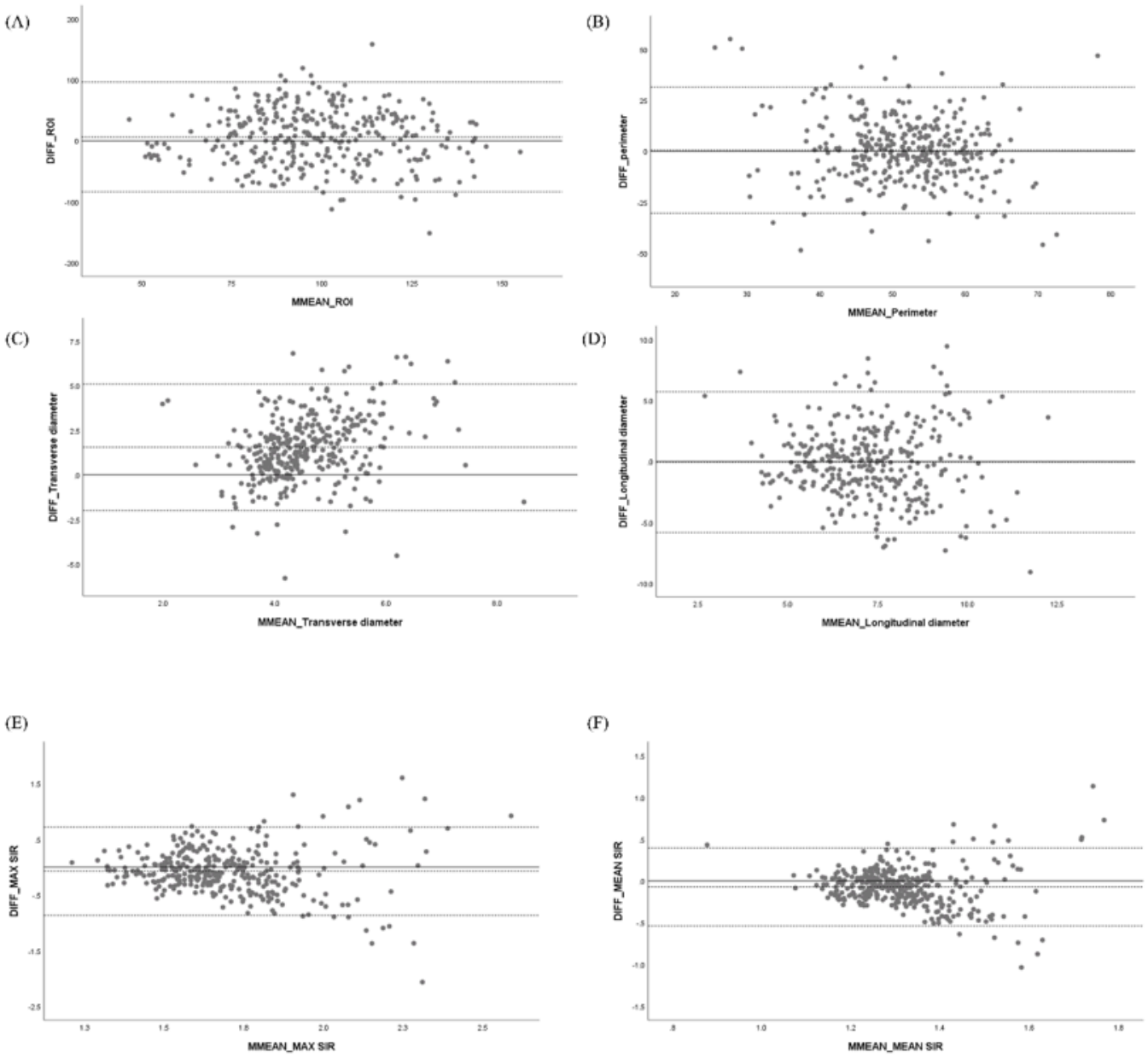


Figure 6

Bland–Altman plots showing agreement between the two readers for thyroid area (a), perimeter (b), transverse diameter (c), longitudinal diameter (d), as well as the mean (e) and maximum (f) thyroid-to-muscle signal intensity ratios (SIRs).

Thyroid ROI area: bias = 6.20, SD = 45.89; limits of agreement = −83.75, 96.14

Perimeter: bias = 0.55, SD = 15.84; limits of agreement = −30.49, 31.61

Transverse diameter: bias = 1.55, SD = 1.81; limits of agreement = −1.99, 5.09

Longitudinal diameter: bias = −0.06, SD = 2.95; limits of agreement = −5.84, 5.71

Maximum SIRs: bias = −0.07, SD = 0.40; limits of agreement = −0.85, 0.71

Mean SIRs: bias = −0.07, SD = 0.24; limits of agreement = −0.54, 0.40

ROI, region of interest; SD, standard deviation.